Hands-On With CCi-MOBILE:
A Cochlear Implant and Hearing-Aid Research Platform

John H.L. Hansen
Juliana N. Saba, Nursadul Mamun, Ria Ghosh,
Ram C.M.C. Shekar, Avamarie Brueggeman, Hazem Younis

Virtual ARO 2021 Workshop

February 19, 2021
1–2:30 PM (EST)

Cochlear Implant Processing Lab (CILab)
Center for Robust Speech Systems (CRSS)
The University of Texas at Dallas
https://crss.utdallas.edu/CILab/

Supported by Grant No. R01 DC010494-01A NIH (NIDCD) Cloud Supplement: NOT-OD-20-073 NIH (ODSS)

DC010494-01A NIH (NIDCD)

- Joint-collaboration between NYU (Dr. Mario Svirsky), UWM (Dr. Ruth Litovsky), and UTD (Dr. John Hansen)
- Laboratory for Translational Audio Research (NYU), Binaural Hearing and Speech Lab (UWM), and Cochlear Implant Processing Laboratory (UTD)

NYU

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

THE UNIVERSITY
OF TEXAS AT DALLAS

Workshop Overview

1-1:30 PM (EST)– Technical Presentation/Overview

- CCi-MOBILE – Research Platform for Speech Scientists
- Research Capabilities

1:30-1:40 PM (EST) – CCi-MOBLE Video Spotlight Series

- Hardware Showcase
- Software Suite Walk-through
- Mobile (Android) Demo
- Subjective Testing & Safety

1:40-2:30 PM (EST) – Breakout Sessions for Q/A

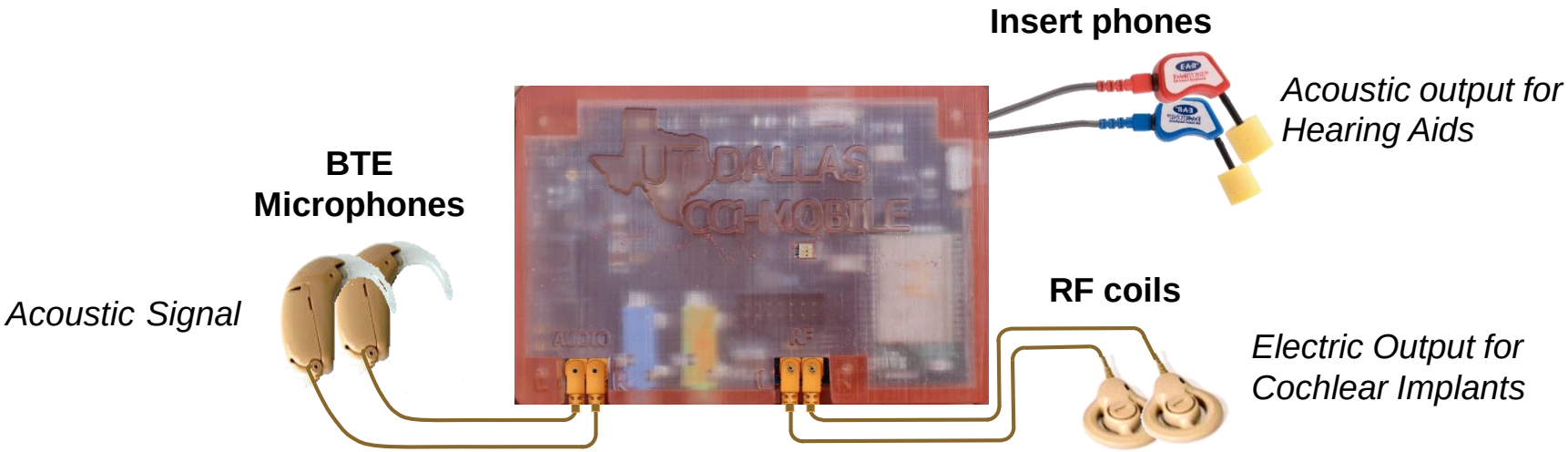
1. General Breakout Room – Dr. John Hansen
   - How to obtain CCi-MOBILE, IRB/NIH Process, and other general questions
2. Software Breakout Room – Nursadul Mamun, Juliana N. Saba, Avamarie Brueggeman
   - Software-related questions, Android/Java-related questions, and conducting experiments
3. Hardware Breakout Room – Ria Ghosh, Hazem A.M. Younis, Ram C.M.C. Shekar
   - Hardware-related questions, hardware specifications, hardware testing paradigm, and cloud-based platform

CCi-MOBILE

CCi-MOBILE Research Platform

- Research interface for cochlear implants* and hearing-aids
- Configured for both **in-laboratory, in-booth,** and **in-field** testing
- Supports time synchronized acoustic and/or electric stimulation
- Plug-and-play system (portable, wearable)

* For implants manufactured by Cochlear Corp.

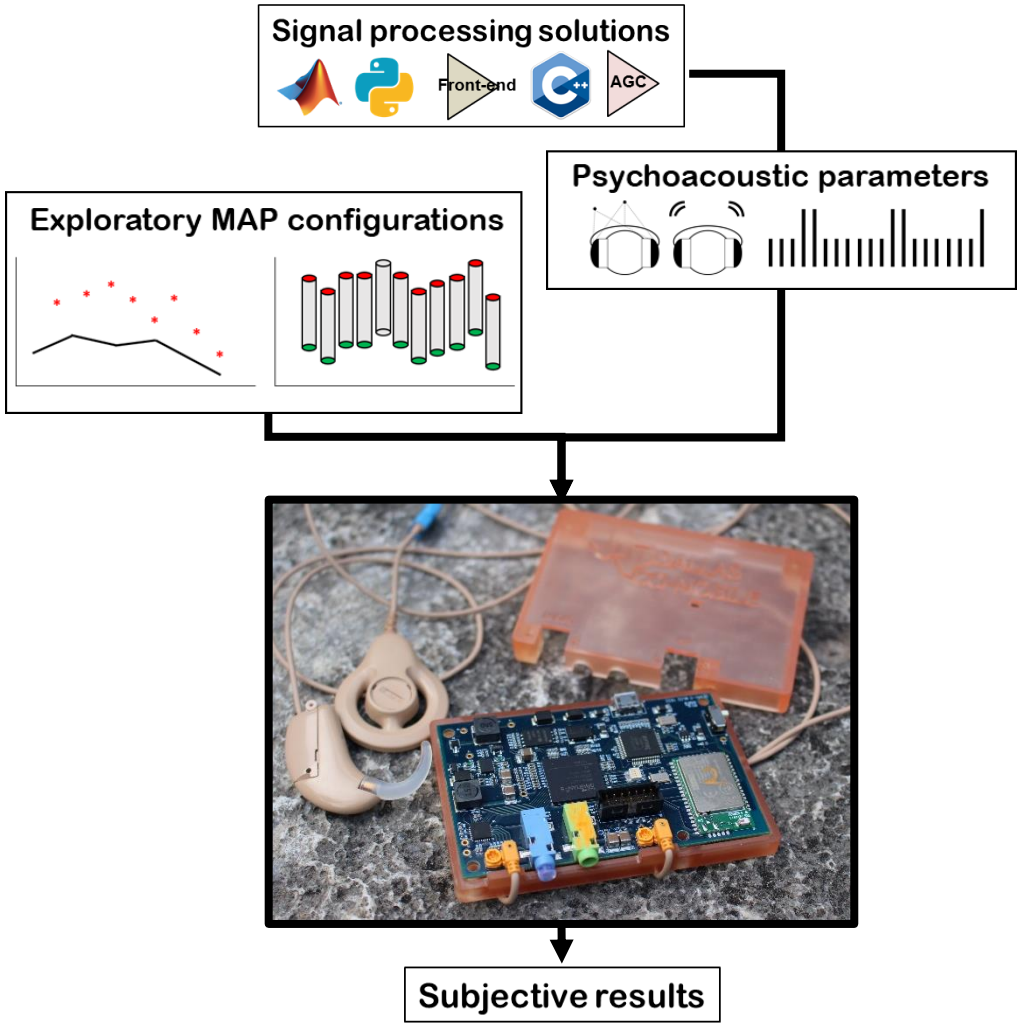


Research Capabilities

Explore & Test

- **Signal processing solutions,** i.e., compression, noise-suppression, speech enhancement
- **Custom experimental designs** with human subjects, i.e., intelligibility in naturalistic environments, localization, modulation detection, etc.
- **Explore fitting parameters**, i.e., attack/release times, MCL/THR, frequency allocations, etc.

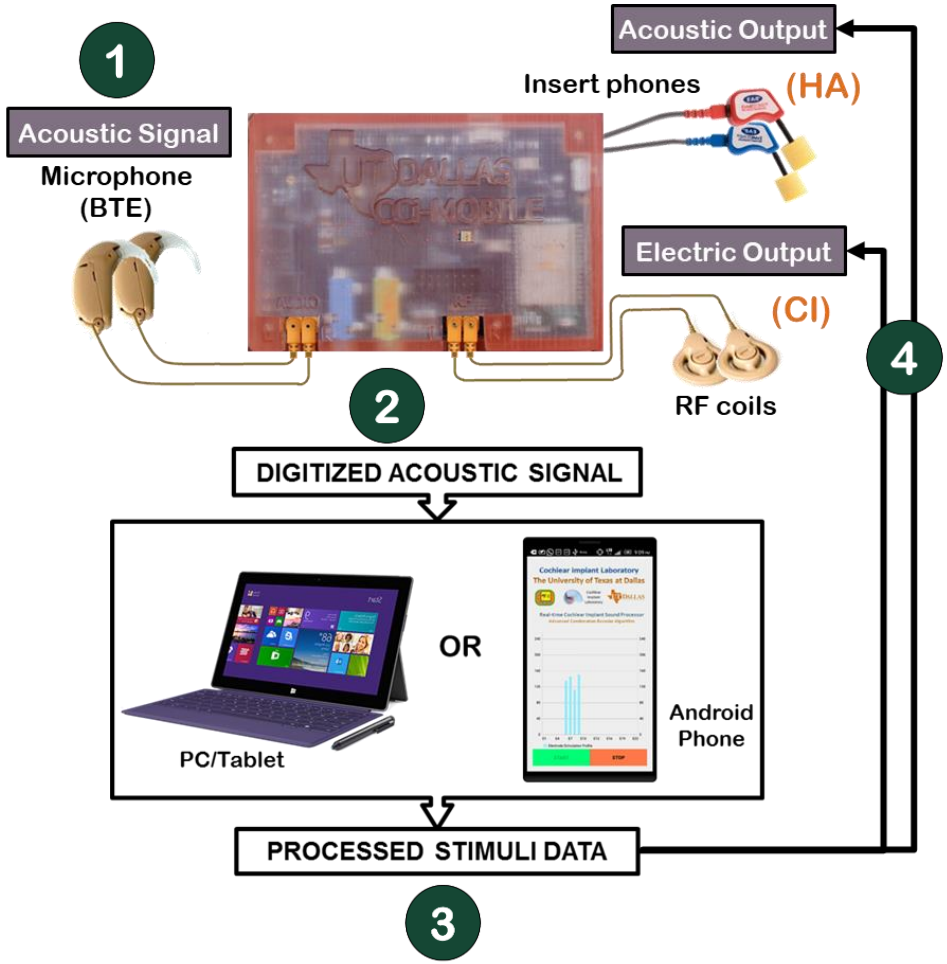
…and so much more



Data Processing

Working Sequence

1. Input – BTE (acoustic) samples at 16 kHz via stereo codec at 5Mbps
2. Transmission – Parallel computation at 8ms data packets
3. Data Processing – FPGA (CCi-MOBILE) receives EAS stimulation, encodes acoustic/electric stimuli
4. Communication – FPGA sends time synchronous data to CI/HA transducers



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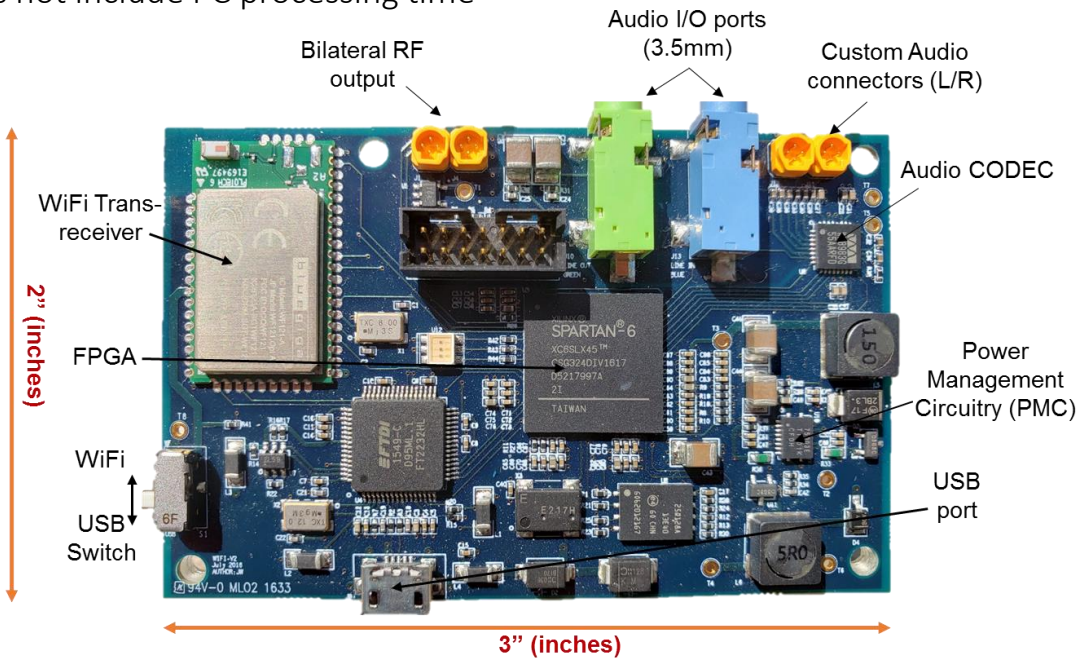
Hardware Design

- FPGA-based design, programmed in Verilog using Xilinx ISE software
- Real-time performance (10.4ms delay*) using incoming/outgoing data on a frame-by-frame basis
  - * Does not include PC processing time
- Data synchronization managed using handshake design techniques
- Implant-specific stimuli generation (for CI24 implants)
  - Sends individual pulse characteristics



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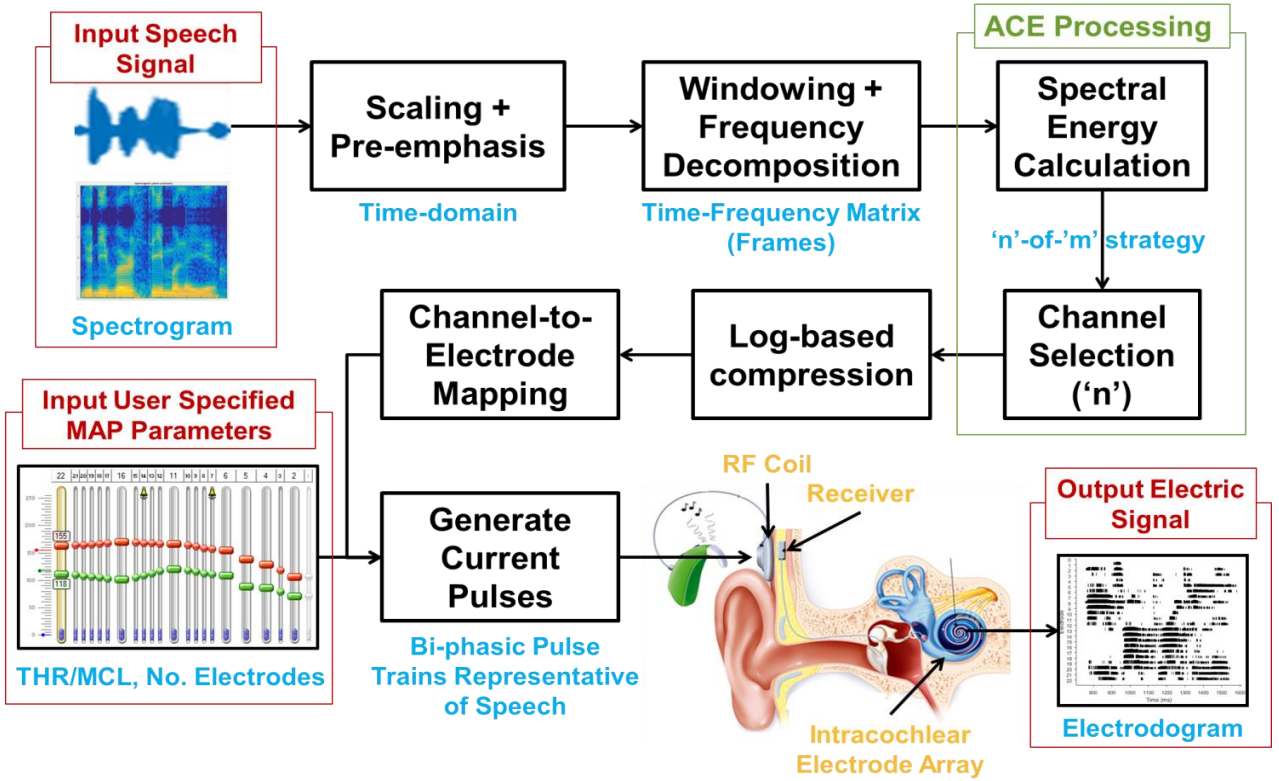
CI Signal Processing

- Adapted from Nucleus MATLAB Toolbox into MATLAB App
- Default stimulation: Continuous Interleaved Sampling (CIS)
- Default sound coding strategy: Advanced Combination Encoding (ACE)



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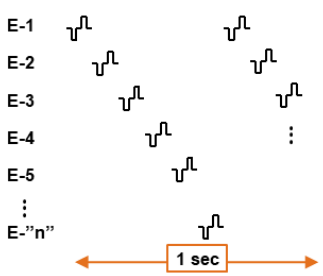
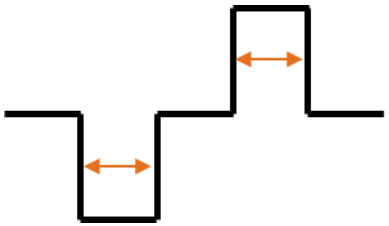
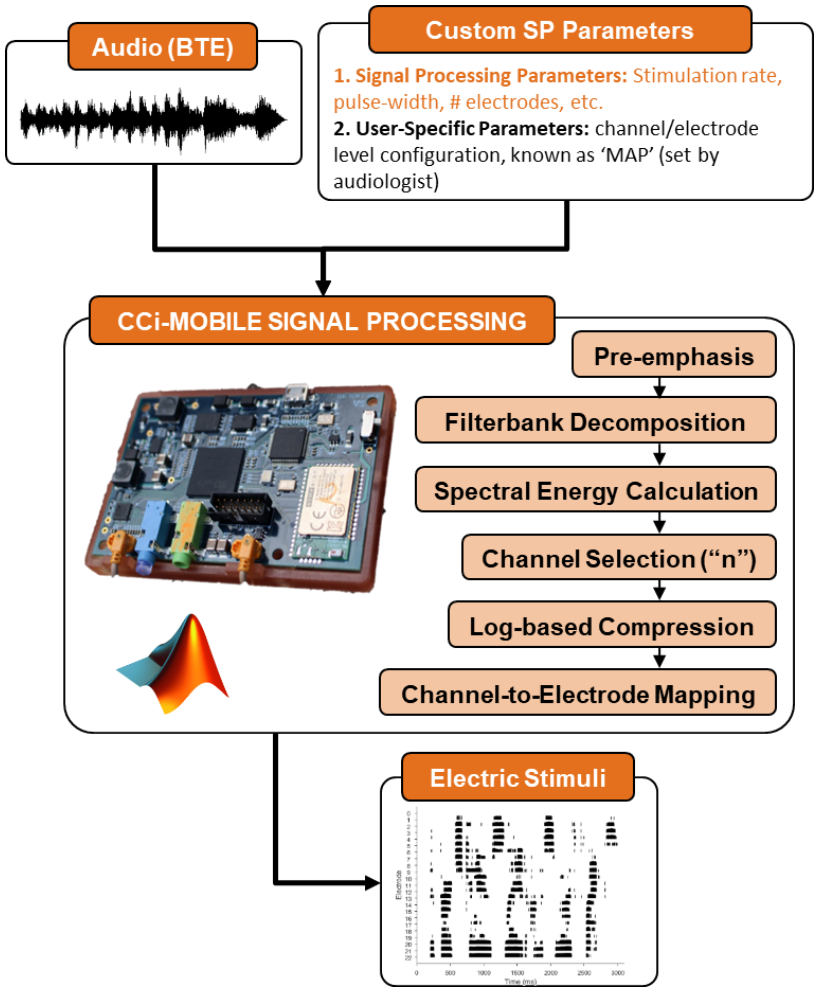
Custom CI Signal Processing

Control Individual Components

- Stimulation Rate (pps/ch)
- Pulse-width (PW)
- Number of Electrodes
- Channel Gains
- Sensitivity
- Stimulation Order
- Etc.





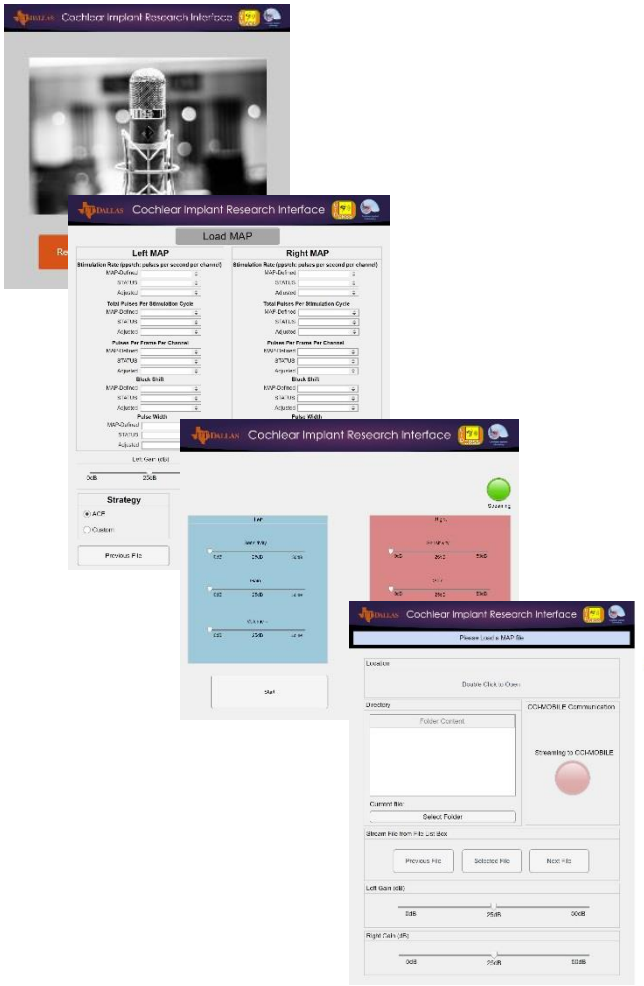


Software Suite

Ready-to-Use Applications

Easy-to-use, GUI-friendly, open-source programs written in MATLAB to help get researchers started

1. **Record/Visualize Audio –** AudioRecorder/ AudioScope generates a time-waveform or real-time microphone input (BTE or HA)
2. **Direct Connect (CI-only) –** RealtimeStimulator implements signal processing routines to stimulate implants directly, without clinical processor
3. **Offline Experiments –** Various programs to stream individual audio files, process using custom strategies, and to set desired MAP/fitting parameters



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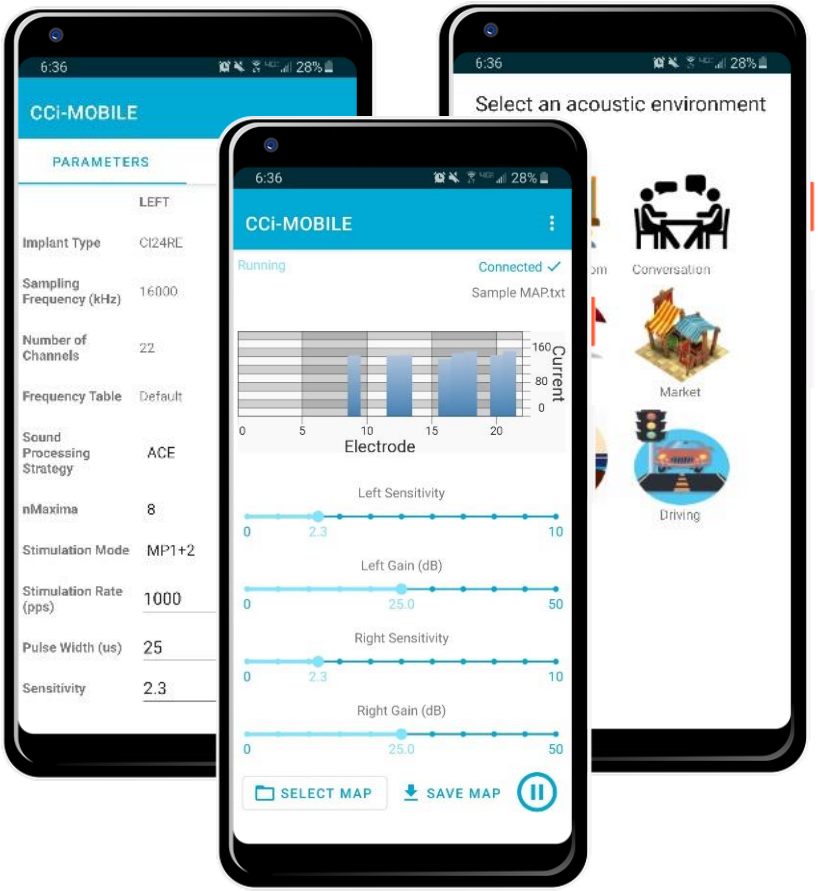
In-Field Testing

Android App

- Real-time performance on Android smartphones and tablets
- Highly suitable for in-field or take-home trials
- Easily adjust signal processing/MAP parameters in real-time
- Quickly select/define pre-programmed environments



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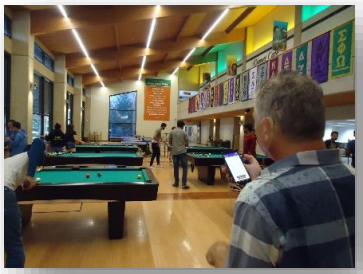
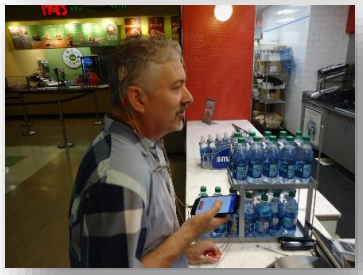
In-Field Testing

- Evaluate algorithms outside the lab in everyday naturalistic environments





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CCi-Cloud Development

- Currently developing a cloud-based platform to support multi-site remote experiments, data-sharing, and cochlear implant user outreach
- AWS services such as “Workspace” & “IoT Core” utilized as components of cloud-based platform
- Supports 3 subdivisions (cloud rooms):

CCi-Share

- Datalogging
- Comparable to “google drive” functionality
- Collaborative space shared among research institutions

CCi-Evaluate

- Remote Experiments
- Longitudinal Testing
- Auditory Training
- Real-time signal processing

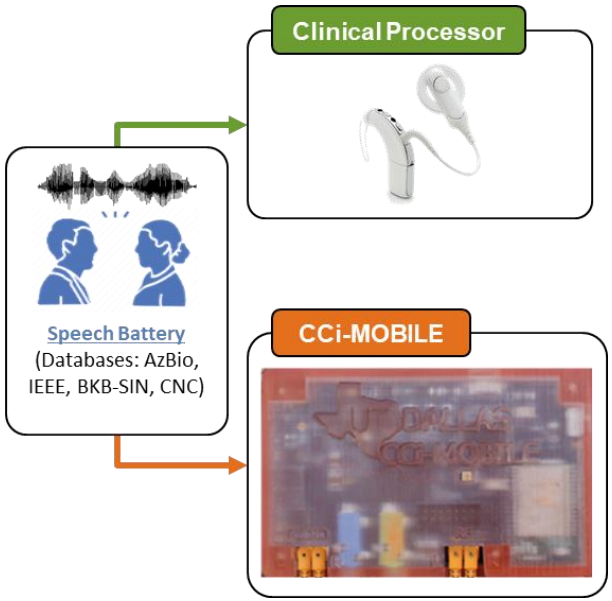
CCi-Connect

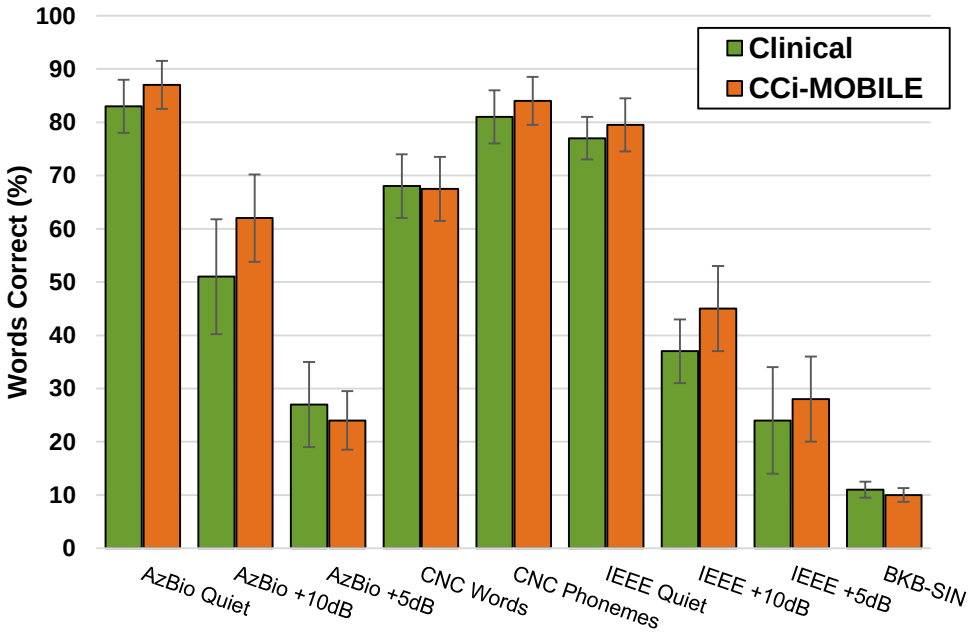
- Cochlear implant user portal
- Website with available resources for existing and potential CI users and researchers

Reliability and Verification

Clinical Processor vs. CCi-MOBILE

- Compared speech intelligibility of CI users (N=8) using 3 sentence databases with various degrees of noise
  - No significant different between clinical processor and research processor (F[7,49]=4.882, *p*=0.069)





Request CCi-MOBILE

Request CCi-MOBILE

How to Obtain CCi-MOBILE for your Institution

Applicants to disclose research interests, objectives of incorporating CCi-MOBILE to support hypotheses, and intended use

- **Memberships** – All CCi-MOBILE units are funded through membership options (full ownership, annual/monthly leases)
- **IRB** – Required at home-institution for use with human subjects
  - Sample IRBs can be provided upon request
- **Hardware Cost –** No-cost hardware, all funds are folded back to support units in the field (updates, repairs, etc.)
- **NIH Investigators –** Supplement requests to obtain CCi-MOBILE
  - Sample request letter can be provided upon request

Membership Tiers

Four Membership Options

1. **Platinum Plus** – Full ownership, two CCi-MOBILE platforms
   - Suggested for use through NIH supplement
2. **Platinum** – Full ownership, single CCi-MOBILE platform
   - Suggest for smaller research labs/organizations/institutions
3. **Gold** – Suited best for short-term research investigations
4. **Silver** – Great for graduate students or intern researchers

For more information:
https://crss.utdallas.edu/CILab/subscription.html

Services/Equipment	Platinum +	Platinum	Gold	Silver
Ownership	100%	100%	Annual	Quarterly
Platform	✓	✓	✓	✓
Second Platform**	✓	✗	✗	✗
Software Suite	✓	✓	✓	✓
Online Resources	✓	✓	✓	✓
Unilateral[1]	✓	✓	✓	✓
Bilateral[2]	✓	✓	★	✗
Bimodal[3]	✓	✓	✗	✗
Android phone	✓	✓	★	✗
Annual Seminar	✓	✓	✓	✓
UTD Course (1-day)	✓	✓	✓	✗
UTD Workshop (3-day)	✓	✓	✗	✗
1-on-1 Tech Support	✓	✓	✗	✗
Replacement Warranty	✓	✓	*	✗
Early Access…	✓	✓	✗	✗
PRICE	$15K one time	$10K one time	$5K per year	$250 per month

[1]Unilateral: BTE, 1 coil | [2]Bilateral BTEs, 2 coils | [3]2 BTEs, 2 coils, bimodal platform/firmware
★ Additional charges to upgrade |*Additional charges for item replacement and/or lump-sum warranty or individual item replacement as per need basis
** Includes additional components (cables, BTEs, coils, phone)

FDA Guidance

- CCi-MOBILE Research Platform is meant for “non-clinical” experimental investigations
- CCi-MOBILE does NOT fall under the scope of the FDA IDE
- Your organization/institution **must have IRB approval** from your respective institution to conduct research with human subjects
- FDA submission (Feb 2017) for FDA-IDE status resulted in the following response:

> “…we have determined that your study does not fall within the scope of the IDE regulation, and an IDE application is not required to be submitted to FDA for your proposed study.” – FDA

CCi-MOBILE Adopters

Platinum Plus Sites

- **New York University** (New York, NY)
- **University of Wisconsin** – Madison (Madison, WI)
- **New Jersey Institute of Technology** (Newark, NJ)
- **Cadwell Industries** (Kennewick, WA)
- **McMaster University** (Hamilton, ON, Canada)
- Universidade Federal de Santa Cararna (Florianópolis, Santa Catarina, Brazil)
- South China University of Technology (Guangdong Sheng, China)

Platinum/Gold/Silver Sites

- Split University (Split, Croatia)
- Shenzhen University (Guangdong Sheng, China)
- **Cochlear Corporation, LLC.**

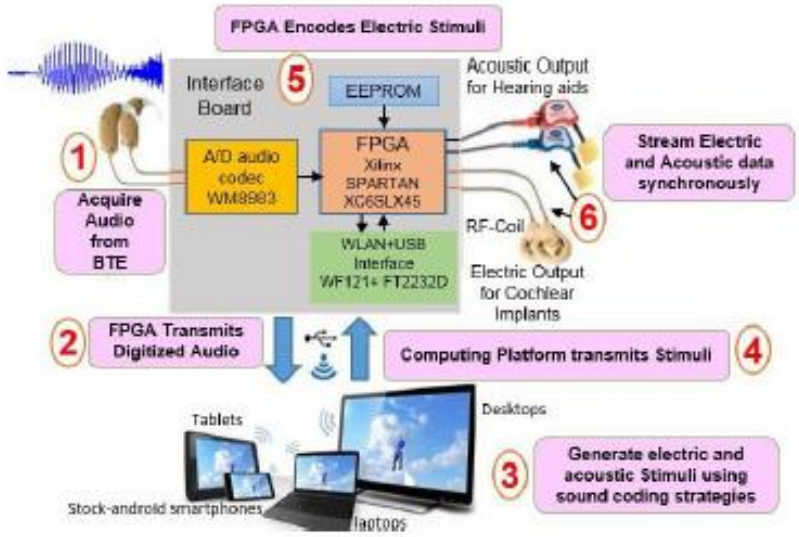
Publications

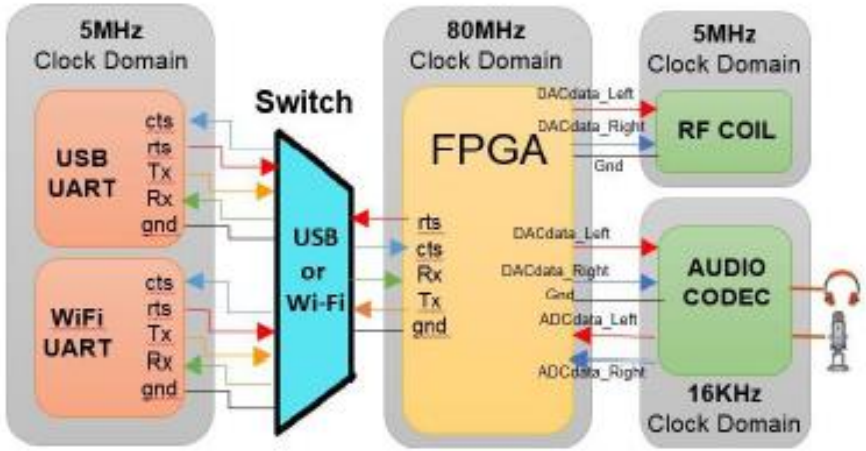
- For more information on the hardware/software processing and verification:
  - Hansen, J.H.L., Ali, H., Saba, J.N., Charan, R.M.C., Mamun, N., Ghosh, R., Brueggeman, A. (2019) IEEE EMBS Inter. Conf. on Biomedical & Health Informatics (BHI), May 2019
    DOI: 10.1109/BHI.2019.8834652

CCi-MOBILE: Design and Evaluation of a Cochlear Implant and Hearing Aid Research Platform for Speech Scientists and Engineers[1]

John H.L. Hansen, Hussnain Ali, Juliana N. Saba, Ram Charan M. C., Nursadul Mamun, Ria Ghosh, Avamarie Brueggeman
CRSS-CI Lab: Center for Robust Speech Systems – Cochlear Implant Processing Lab
Department of Electrical & Computer Engineering, The University of Texas at Dallas, Richardson, USA
(John.Hansen; Hussnain.Ali; Juliana.Saba; RamCharan.ChandraShekar; Nursadul.Mamun; Ria.Ghosh; Avamarie.Brueggeman)@utdallas.edu

Abstract—**Hearing loss is an increasingly prevalent condition resulting from damage to the inner ear which causes a reduction** of the prevalent technology that can help to provide/improve hearing sensation. Success of this technology, to a vast extent,





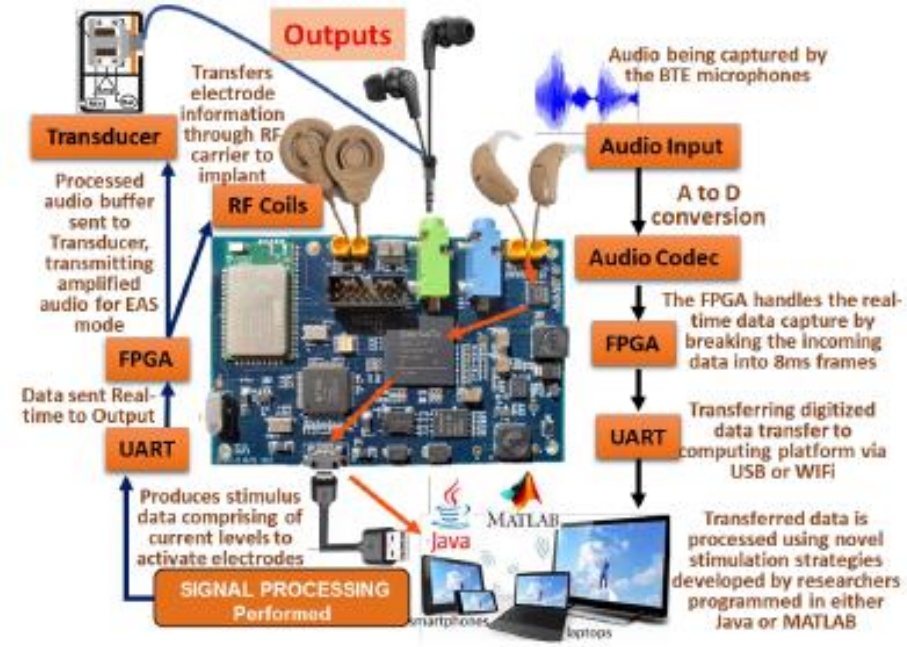
Publications

- For more information on CCI-MOBILE, developmental design, history, hardware, system, etc.
  - Ghosh, R., Ali, H., Hansen, J.H.L. **Submitted** to IEEE Trans. Biomedical Engineering (TBME-00089-2021); Jan. 16, 2021

CCi-MOBILE: A Portable Real Time Speech Processing Platform for Cochlear Implant and Hearing Aid Research

Ria Ghosh, *Student Member, IEEE*, Hussnain Ali, *Member, IEEE*, John H.L. Hansen, *IEEE Fellow, IEEE*

Abstract— **Hearing impairment is a pervasive problem which occurs due to the detrimental damage caused to the inner ear.** processor. The electrode array consisting of 12-22 electrodes is surgically implanted in the cochlea (inner most part of the ear) to mimic the functionality of the healthy hair cells in normal-



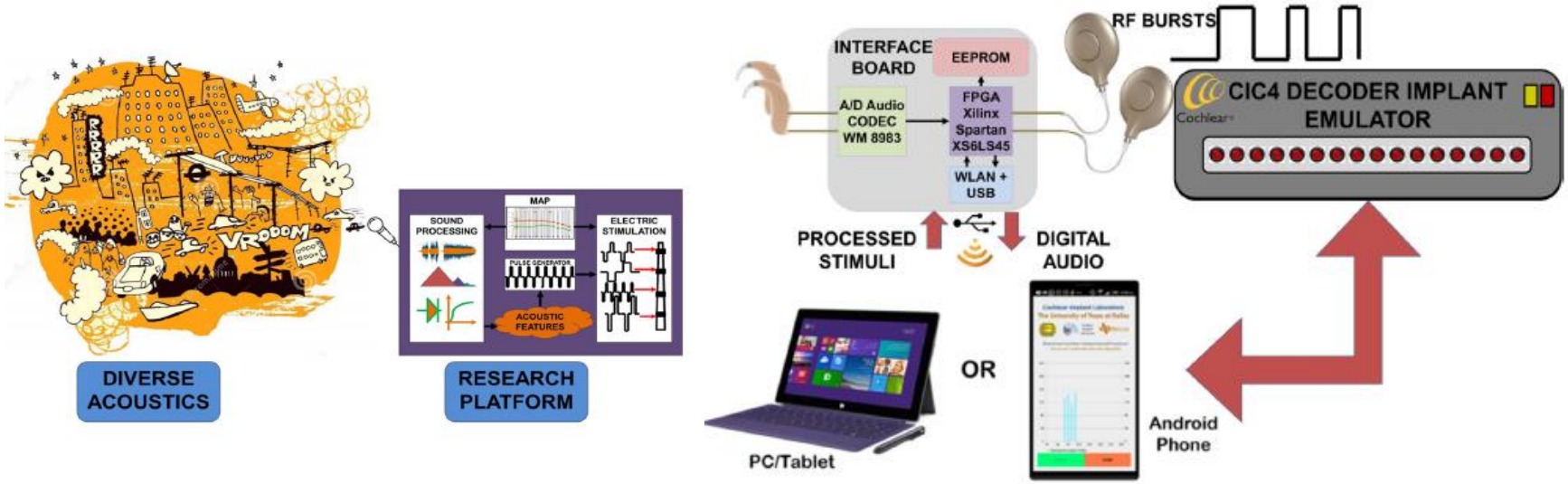
Publications

- For more information on testing paradigm
  - Shekar, R.C.M.C., Hansen, J.H.L. (2021) Journal of the Acoustic Society of America, 149(1): 229-245.
    DOI: 10.1121/10.0002989

JASA ARTICLE

An evaluation framework for research platforms to advance cochlear implant/hearing aid technology: A case study with CCi-MOBILE

Ram C. M. C. Shekar and John H. L. Hansen[a)]
Cochlear Implant Processing Laboratory, Center for Robust Speech Systems (CRSS-CILab), Department of Electrical and Computer Engineering, Jonsson School of Engineering and Computer Science, University of Texas at Dallas, Richardson, Texas 75080, USA



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   - Hardware-related questions, hardware specifications, hardware testing paradigm, and cloud-based platform

Spotlight Video Demos

Software Spotlight

- Applications/software suite demonstrations
- How to create custom GUI (AppDesigner)
- How to use/run MATLAB Scripts

Mobile Spotlight

- Demonstration of Android App in-field
- How to run Android App
- How to find open-source code

Hardware Spotlight

- Walk-through of FPGA design
- How CCi-MOBILE generates stimulation
- How data transmission is processed

Experiment Spotlight

- Overview of board verification
- Proposed infrastructure for Cloud setup

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Q/A Breakout Rooms

Questions about… CCi-MOBILE?

- Breakout Room #1
- General questions
- How to obtain CCi-MOBILE
- IRB, FDA-IDE concerns
- How to request supplement/draft IRB

Moderator: Dr. John Hansen

Questions about… hardware? Safety?

- Breakout Room #3
- How CCi-MOBILE was designed
- How CCi-MOBILE transmits and sends data
- Testing paradigm
- Proposed infrastructure for Cloud setup

Moderators: Ram & Haz (Research Assistants)

Questions about... running experiments/signal processing?

- Breakout Room #2
- How to test custom processing strategies
- How to evaluate custom MAP parameters
- How to access/use the applications
- How to run Java/MATLAB scripts

Moderators: Juli, Ava, & Mamun (Research Assistants)

- Visit our website for documentation, demos, software, and updates
  - https://crss.utdallas.edu/CILab/